Paleoseismic Studies along the Eastern Carson Valley Fault System

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Craig M. dePolo
Nevada Bureau of Mines and Geology
University of Nevada, Reno
Reno, Nevada 89557
Tel. 775.784.6691
Fax. 775.784.1709
email: cdepolo@unr.edu

Background

The Eastern Carson Valley fault system (ECVFS) is a large system of over 200 individual fault traces that lies within the Reno-Carson City urban corridor in western Nevada. The ECVFS is 8 to 10 km wide, and covers the eastern third of Carson Valley, an area being rapidly developed with houses. The system is a complex zone of subparallel, nested, mostly east-dipping faults, with an overall length of 21 km. The geomorphic expression of the faults is spectacular, consisting of fault scarps, abrupt fronts on uplifted hills, over-steepened bases, fault-captured drainages, tonal and vegetation lineaments, and a series of interior valleys and down-dropped blocks formed by prominent west-dipping faults. A young paleoseismic event can be detected in the geomorphic expression along several faults in the system. This event, which shows up spectacularly on existing low-sun-angle photography and in the field, is expressed by small single-event fault scarps, small uplifted stream terraces, swales and disrupted ground, and oversteepened parts of larger, compound fault scarps. The distributed nature of the faults and paleoseismic rupture indicates a substantial surface-faulting potential exists locally.

The ECVFS generally has a north to north-northwest strike, with individual faults commonly having northerly strikes, but ranging from northwest to northeast striking. Individual fault traces are commonly 1 to 2 km long, with some traces as much as 4 km long. Cross-strike distances between traces are small, typically 20 to 300 m. Total vertical displacement across individual fault traces ranges from a meter to a little over 100 m, but is commonly a few meters to tens of meters. In addition to the normal dip-slip displacement that is clear, the ECVFS may also have a component of strike-slip motion based on preliminary observations of slickensides, left-stepping patterns of fault traces, and flower structures observed in exploratory trenches. A notable character of the young paleoseismic rupture is that in most cases it does not rupture along the strike of the ECVFS, but appears to rupture diagonally across adjacent faults. The exact kinematic model for the ECVFS is uncertain. The extension may be part of the bending of "Carson Valley" in response to the Genoa fault of the Carson Range fault system (bounding the western side of Carson Valley), or it may be part of a complex formation of ancestral Carson Valley in late Pliocene. The faults make up a very complex pattern that reflects complicated tectonics. This could be explained by faults that are inherited from an earlier tectonic regime and are being reactivated by, or are progressively evolving into, a new tectonic regime, that has a component of wrenching motion.

Investigations Undertaken

To date, three trenches have been dug along the ECVFS, at least five additional trenches have been investigated, and a preliminary fault map has been produced for the system. The trenching investigation was focused on the largest fault in the ECVFS, along a portion that underwent displacement during the young paleoseismic event visible on photographs. This fault is in the eastern part of the system. Although the investigation of a single fault is just the beginning of characterizing such a widespread fault system, it is the largest fault and should give a good initial view into the activity of the system. Other trenches dug by consultants for housing developments were reviewed on the western side of the ECVFS. The preliminary fault map is at a scale of 1:24,000 and shows the fault pattern well. This map will be enhanced to show the locations of paleoruptures, and the geomorphic expression of faults will be annotated.

Trenching Studies

The trenches excavated for this study are along the northern part of the Fish Spring Flat fault zone. This fault zone has a mapped length of 8.5 to 13.5 km, depending on which faults are part of the zone at its ends. Three trenches were dug along the same trace, each across a fault scarp on an uplifted fluvial terrace of a different height. Trench 1 is a across a small 50- to 80-cm-high, single-event scarp bounding the youngest uplifted terrace in a small drainage crossing the fault. At the trench site the fault dips to the west, and incrementally drops the baselevel of the stream channel during earthquakes, causing channel incision and isolating stream terraces. The footwall rocks are made up of easily erodible latest Tertiary alluvium and Quaternary alluvium, and respond relatively quickly to this baselevel change. Trench 2 is across the fault scarp bounding the second highest terrace. This terrace appears to be about two to three times higher than the lowest faulted terrace. Trench 2 exposures revealed that this is a strath terrace, making correlation across the fault of deposits difficult to impossible. Trench 3 is across a large, compound fault scarp bounding the third highest terrace in the drainage. The coarsest alluvium encountered at the site was at trench 3 in the alluvium deposited on top of the terrace, and it was hoped that these gravels and cobbles would make distinct proximal facies of colluvial wedges, allowing paleoevents to be more confidently identified; trench 3 was also made the deepest to allow the most paleoevents possible to be encountered.

Preliminary logs have been made of the trenches, but are still being detailed, and interpretations are still being developed at this time. Preliminary observations indicate that there is evidence for three paleoseismic events in the trenches.

Results

All trenches clearly show the very youthful paleoevent that is visible at the surface (paleoevent 1), and trenches 2 and 3 have evidence for at least two earlier events (paleoevents 2 and 3).

The youngest event is latest Holocene, probably occurring within the last 1000 years, based on the young surface expression with steep scarps and disrupted ground, the incipient nature of colluvial deposits associated with scarps from this event, and the lack of soil development on the uplifted terrace isolated by this event. Fluvial knick points from this event near the trenches are not well developed, but the general rejuvenations of the stream channels due to the event are still visible in the reaches of stream channels near the fault supporting a youthful age. This event caused vertical surface displacements along the main fault of about 50 to 80 cm, commonly distributed or stepped over a 1-m-width, and created small offsets and fissures in the hanging wall. Given the steep nature of faults exposed, probable flower structures, and small thrusts, there was likely a right-lateral component during paleoevent 1 as well.

The next oldest event, paleoevent 2 is expressed in trenches 2 and 3 as a colluvial package with a well-developed argillic horizon in it, and a silty and very fine sand vesicular A horizon on top. Colluvial deposits have proximal facies within 1 to 2 m of the main fault, consisting of isolated rocks deposited at the base of a paleo-scarp and gravel deposited on scarp colluvial slopes. Most of the rest of the colluvial deposits are finer grained in nature, with isolated gravel. In trench 3, much of this fine-grained deposit may have a large eolian input because it is generally a uniform, very fine sand. The vesicular A horizon on top is buried by the incipient colluvial wedge developing from paleoevent 1. The argillic horizon developed in the colluvial wedge from paleoevent 2 indicates some antiquity, but may have some primary clay input from the argillic horizon developed in the terraces on the footwalls. Associated carbonate horizons are weakly present on the slopes, but are better developed near the base of the slope. This is a difficult area to casually use soils as an indicator of age because it is near the boundary between mollisols and ardisols, nevertheless a latest Pleistocene age to paleoevent 2 seems likely, given soil development.

A colluvial deposit from paleoevent 3 is also present in trenches 2 and 3, and consists of a wedge of colluvium that is up to 1.2 m thick in trench 2. The base of the colluvial wedge is uncertain in trench 3.

Deposits are thus far barren of any visible, reliable charcoal or organics that can be meaningfully dated, and radiocarbon dating of bulk deposits (probably from the buried A horizons) will likely be attempted.

Several trenches dug by consultants across local faults revealed the most recent activity of some fault traces on the west side of the ECVFS. Given the rapid nature of these trench studies, no definitive information was gained, but in several trenches, the youngest event offsets young-appearing mollic A horizons that have little or no associated B horizons. In addition, relatively loose fissure filling deposits caused by the event have little or no soil development. These observations indicate a young, probably Holocene paleoevent occurred along several of the faults examined. This event may predate paleoevent 1 at trenches 1, 2, and 3, because it lacks the same very youthful surface expression, and postdates paleoevent 2 because of a lack of similar soil development in event deposits and some deposits offset by the event. Thus, three to four paleoearthquakes have been identified along the ECVFS, possibly including multiple Holocene events.

In summary, at least three or four paleoearthquakes have been revealed thus far in trenching studies along the ECVFS, with one or possibly two are Holocene. Observations from the trenches thus far are consistent with a right-lateral component along the ECVFS, but are not definitive.

Nontechnical Summary

Three excavations and several consultants' trenches have been examined to develop a paleoearthquake history along the Eastern Carson Valley fault system. This system is located in a rapidly developing portion of the Reno-Carson City urban corridor and was not previously studied. The system consists of over 200 faults, and has evidence of multiple-fault ruptures. Three trenches, excavated along the largest fault in the system, reveal at least three paleoearthquakes, with the most recent likely being within the last 1000 years. An additional event may be evident in the western part of the system as viewed in consultants' trenches.